Block Pivot Table, Fork and Pallet Engineering Design
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Previous preliminary designs of the block raiser table have allowed space for 'forks' supporting the assembled block when rotated to the vertical position. Because of the cost to form, bar, and pour a concrete floor with many slots becomes expensive, previous designs have limited the number of forks to seven or eight.

Recently, a decision by the project management advocated changing the baseline scheme to a flat floor in the detector hall and the detector supported on a 'pallet' to help control the building costs. If forks were used to support the pallet, the forks would have to nestle into the pallet. Alternatively, the pallet could be attached to the table using a moment connection. Each has been investigated.

Ang Lee has provided stiffness criteria for the pallet and block pivoter based on the allowable deformations in the assembled PVC extrusion block. Key results provided by Ang indicate that the tip of the forks (or end of the pallet) should not deflect more that one half inch (0.5") to keep this short term stress on the empty block on par with the long term stress of a filled block sitting on a rigid surface. In the transverse direction, and assuming an eighty-four inch fork spacing, a 0.008" deflection between forks has been shown to be acceptable.

Three alternative designs compatible with the flat floor have been evaluated:
1) The first design addressed an adaptation of the block pivoter with an eight fork design and a 36 inch deep pallet fabricated from two inch square box section trusses.
2) The second design analyzed a block raiser solution with table portion made from twenty-four 20 inch deep, 8 inch wide box sections and a cantilevered pallet made from twenty-four 14 inch deep by 6 inch wide box sections. (See Nova Note 1152).
3) The third and final design analyzed uses a deep plate structure table with a cantilevered pallet made from twelve 18 inch deep by 8 inch wide box sections.

The first solution using a deep pallet was shown to work and meet the deflection criteria. However, the thirty-six inch deep truss structure pallet, if adopted, would require the building to be taller than if the pallet were shallower. Each thirty-six each deep truss structure pallet would weight about 6500 pounds and likely cost about $13,000 (using $2 per pound for a cost including material (at 50 cents per pound) and $1.50 per pound for the cost of fabricating the truss). Such a design also provides a suitable 'witness space' to allow a scintillator leak to be easily seen. While this solution meets the deflection criteria, a solution with a lower pallet height would be preferable as this would reduce the required building height.

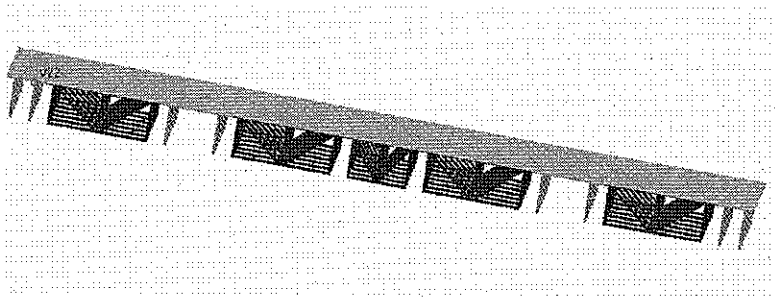


Image 1
Screen capture image of the Solid Model of the thirty-six inch deep truss structure pallet considered in the first solution.

Since the idea of using a 14 inch pallet has been recently re-mentioned, the geometry of a table and pallet shown in NOvA note 1152 was checked for deflection. A finite element model using beam elements was used to evaluate the deflection of the pallet end when the table is vertical. A 13,041 pound load (313,000 pound weight of the empty PVC block equally distributed on 24 cantilevered members). Results of this analysis are shown in figure 1.

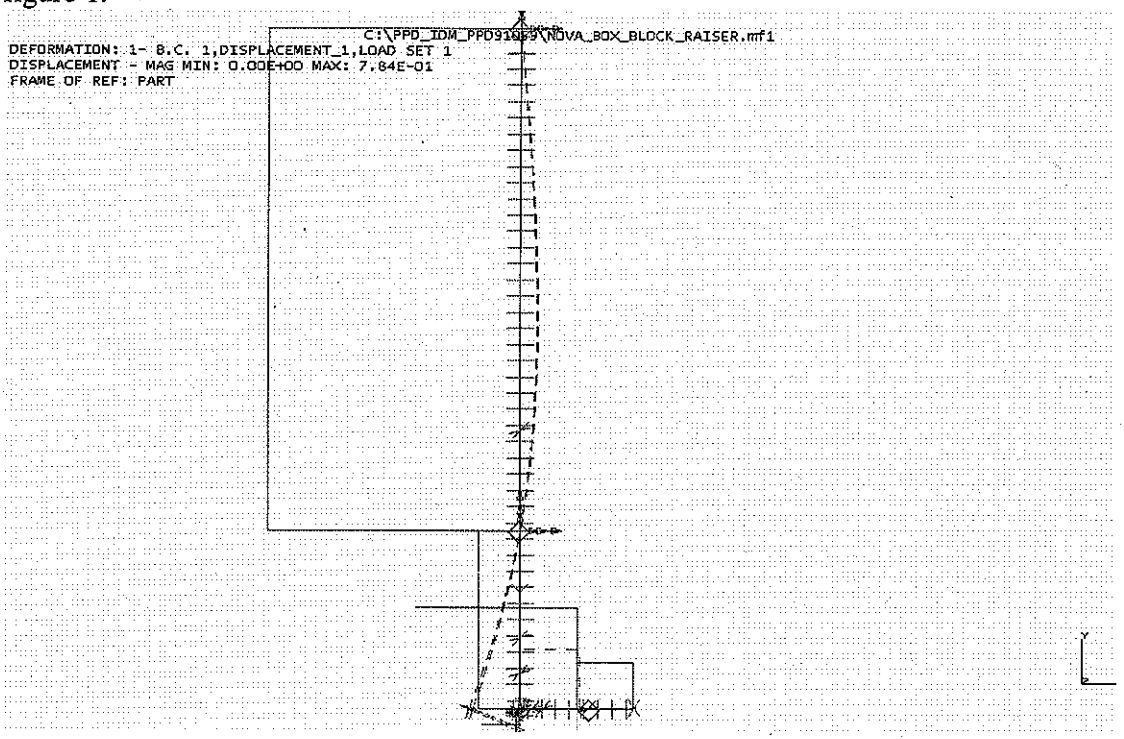


Figure 1
FEA Results of the deflection of a box beam block raiser and cantilevered pallet. Deflection at the tip is 0.78 inches.

In figure 1, the dashed purple line represents the deformed shape of the table and cantilevered pallet. The green lines indicate the original shape while the orange indicate the beam elements. The red lines are simply dimension lines remaining from the geometry creation.

The above result indicates that the block raiser design shown in note 1152 does not meet the deflection criteria. A hand calculation of the same geometry was performed to check the validity of the FEA and the hand calculation gives a deflection result of similar magnitude when the rotations of the 20 inch deep by 8 inch wide box section table members are considered. The deformed shape in figure 2 shows that the table members rotate due to the induced moment from the cantilevered pallet. This rotation is responsible for the majority of the deflection at the end of the pallet. Hand calculations shown in the appendix of 1152 as well as the hand calculation performed as a check of the FEA model agree that the deflection of the pallet alone is only about $1/8^{th}$ of an inch. This suggests that the stiffness of the table needs to be increased to limit the deflection.

Consequently, the third concept analyzed used a seventy-two inch deep table and twelve 18 inch deep pallet members. Since only twelve pallet members were used, the load applied to each member was 313,000 / 12 pounds (26,100 pounds). Results are shown in figure 2.

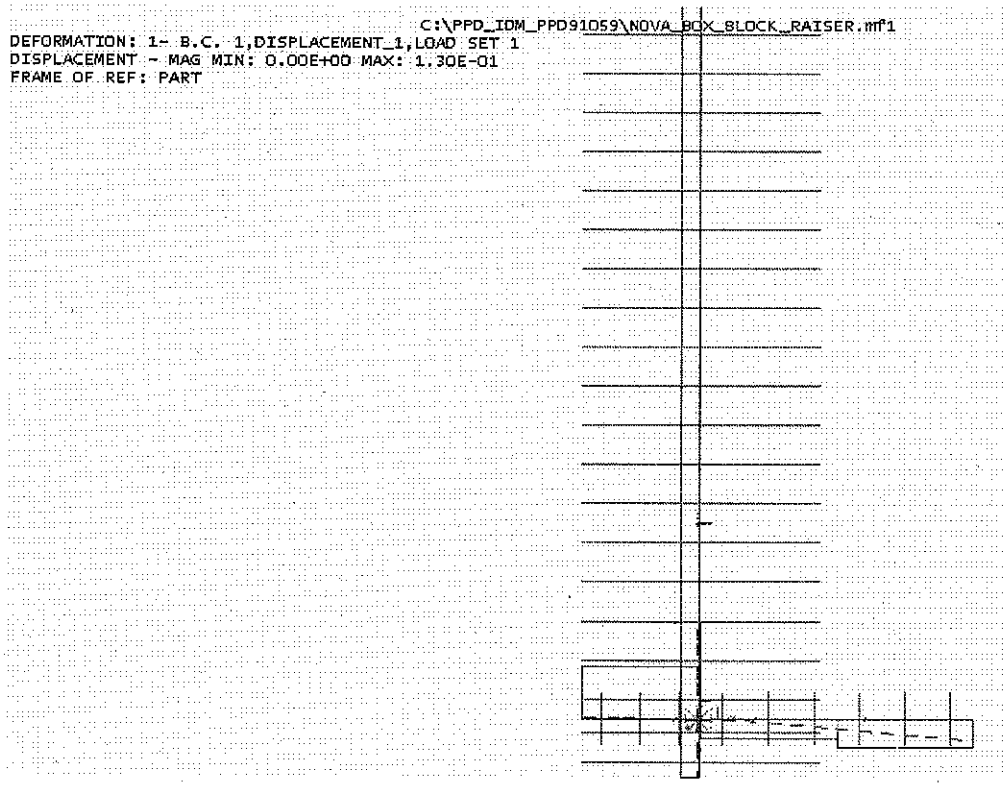


Figure 2
FEA Results of the deflection of a plate structure block raiser and cantilevered pallet. Deflection at the tip is 0.13 inches.

In figure 2, the dashed purple line represents the deformed shape of the table and cantilevered pallet. The green lines indicate the original shape while the orange line segments indicate the beam elements. The red lines are simply dimension lines remaining from the geometry creation. Note that the deflection of the vertical purple line representing the table is nearly indistinguishable from the original geometry.

The above result indicates that the block raiser design using very deep members for the table and a pallet constructed of 18 inch deep tubes meets the deflection criteria presented by Ang Lee. In fact, the stiffness in the beam direction (the direction thru a block) is better than what is required.

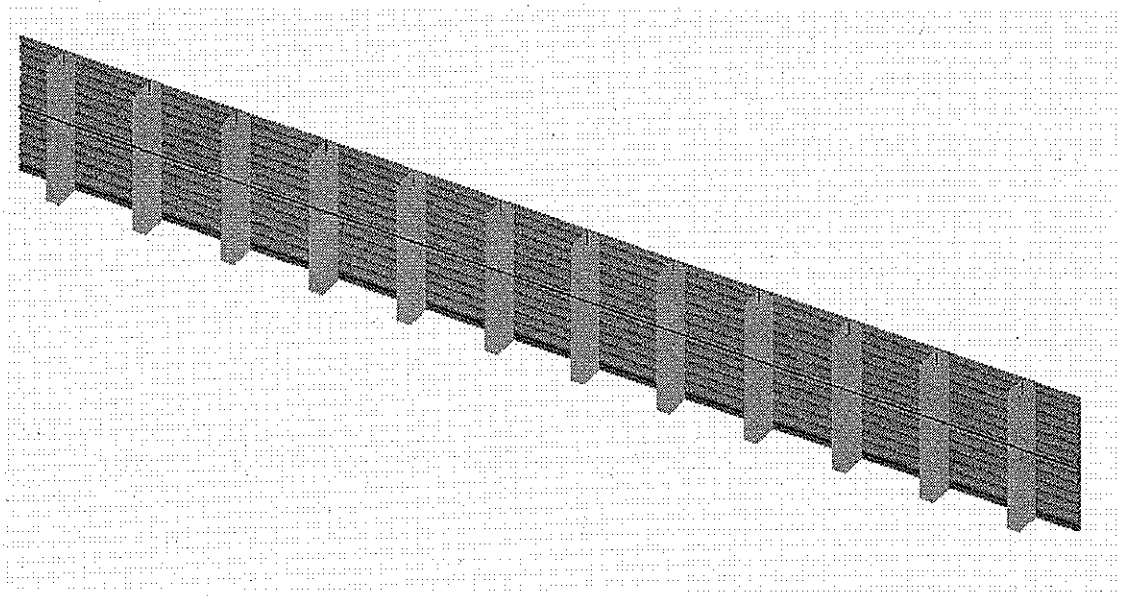


Image 2
Bottom View of a Pallet with twelve 18 inch deep by 8 inch wide box beam cantilever members and fourteen 3 inch by 2 inch transverse stringers.

Weight of the pallet shown in Image 2 is about 9500 pounds. Assuming the raw cost of the steel is 50 cents per pound and the fabrication costs are 75 cents per pound (approximately half the cost of the truss fabrication due to the simpler design) results in a cost of about $12,000 per pallet.

Deflections of the 3 inch by 2 inch stringers loaded with a uniform load of 36 pounds per linear inch are shown in figure 3. 36 pounds per linear inch is the loading from the empty PVC block with an estimated empty weight of 313,000 pounds, 620 inches wide, and fourteen 3 inch by 2 inch stringers. This loading assumes that the empty PVC block has no inherent stiffness.

Hand calculations estimate the deflection at 0.024 inches for the same conditions as a cross check of the model.

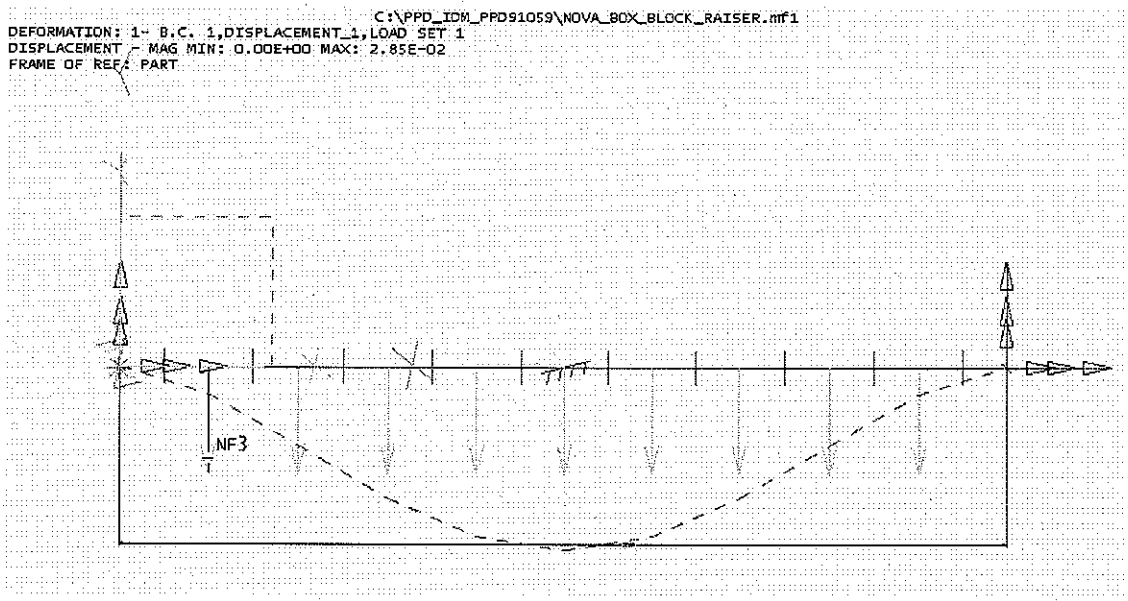
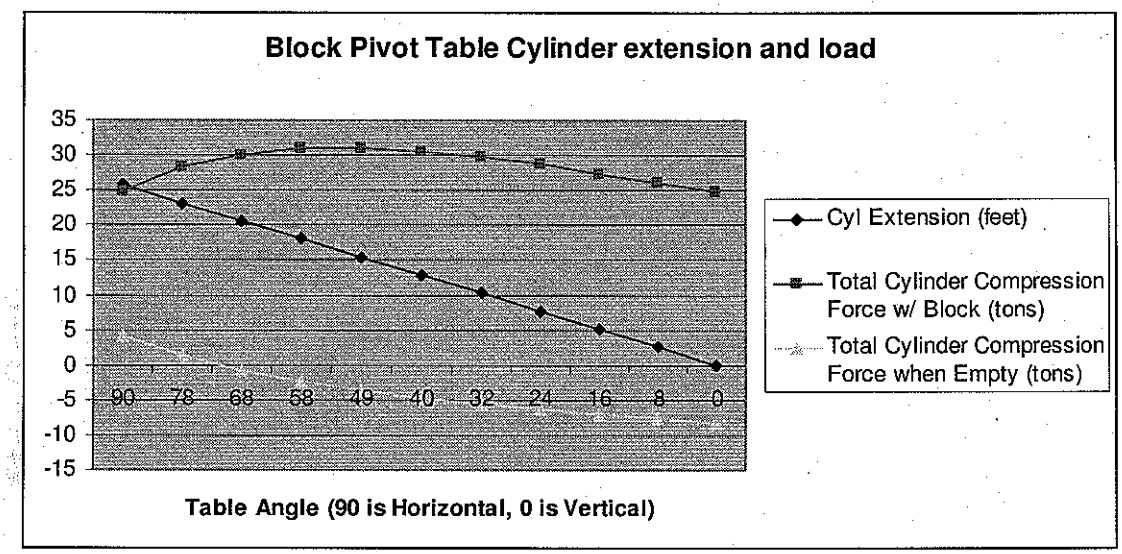


Figure 3
Deflection of the transverse 3 inch by 2 inch stringer between each 18 by 8 box beam on the pallet due to a uniform 36 pounds per linear inch load.
Total deflection is 0.028 inches.

While this deflection may be acceptable for the empty condition, the estimated maximum weight of a filled block is 1.2 million pounds. This gives a linear loading of 136.8 pounds per inch. Resulting stresses would be about 13 ksi and deflections would approach 0.1 inch. This deflection may not be acceptable and will likely require an additional evaluation by Ang.

So, while this remains a work in progress, a couple conclusions can be reached. These conclusions indicate that a cantilevered pallet is feasible and likely superior to a block raiser with forks because while the pallet costs are about the same, the cantilevered pallet design uses less vertical space in the building. The stiffness of the table has also been shown to be very important in meeting the deflection criteria.

Vertical Distance from Assembly Table top to Floor (table horizontal)	317 inches
Maximum Vertical Distance from Floor to top corner of 31 plane block (at nominal dimensions) when pivoting	651 inches
Estimated Pallet Weight	10,000 pounds
Depth of Pallet	20 inches
Deflection of Pallet between18" by 8" members with empty block	0.028 inches
Deflection of Pallet between 18" by 8" members with full block	0.1 inches
Deflection of Pallet Cantilever with empty block	0.13 inches
Hydraulic Cylinder closed Length	76 inches
Hydraulic Cylinder Length when Table is Horizontal	309.02 inches



Graph 1
Hydraulic Cylinder Extension (feet), and Compressive Load (tons) For the Pivot Table Design Using Two Cylinders and a Pivot Location Near the Block Center Of Gravity.

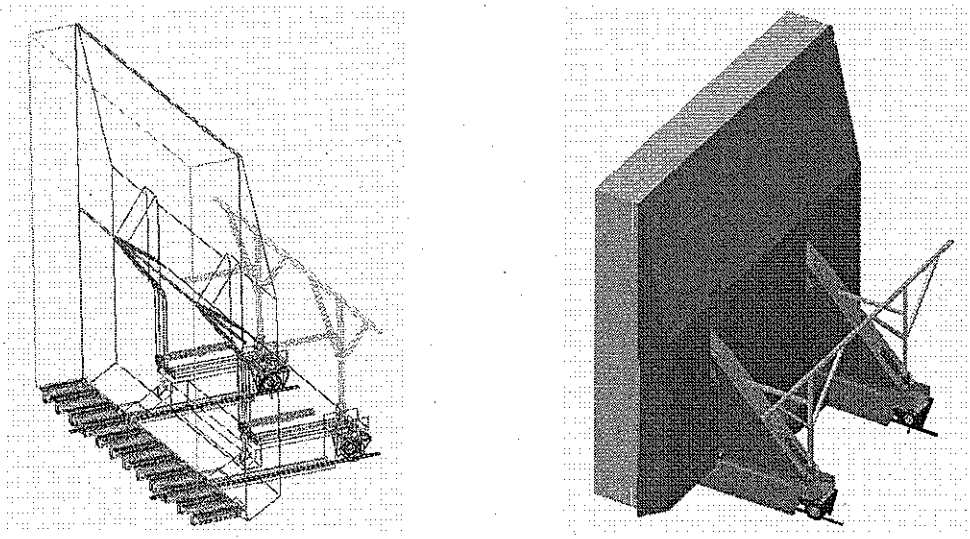


Image 4
Two Isometric Views of the Block Pivot Table Shown in the Vertical Position.
Block is shown in Violet, Table is in Blue, Structure in Orange and Purple

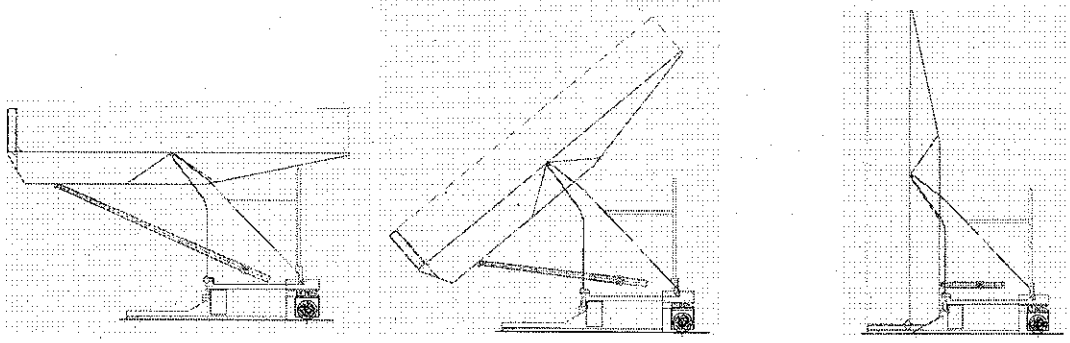


Image 5
Three Side Views of the Block Pivot Table Showing the Block in the Horizontal, Intermediate, and Vertical Positions.

Key parameters used in the block pivot table design include:

Estimated PVC Extrusion Block Weight	313,000 pounds
Estimated Pivot Table Weight	150,000 pounds
Depth of Pivot Table	6 feet
Distance from Table Surface to Pivot centerline	4 inches
Vertical Distance from Pivot to Cylinder Centerline (table vertical)	216 inches